Real Thermal Inertia for Soil Moisture Estimation in Agricultural Areas using Airborne Remote Sensing

Daniel Spengler[1], Andreas Steinberg[1], Christian Hohmann[1], Friedhelm Schwonke[2] & Sibylle Itzerott[1]

[1]*Helmholtz-Centre Potsdam - GFZ German Research Centre for Geosciences*
[2]*Federal Institute for Geosciences and Natural Resources - BGR*

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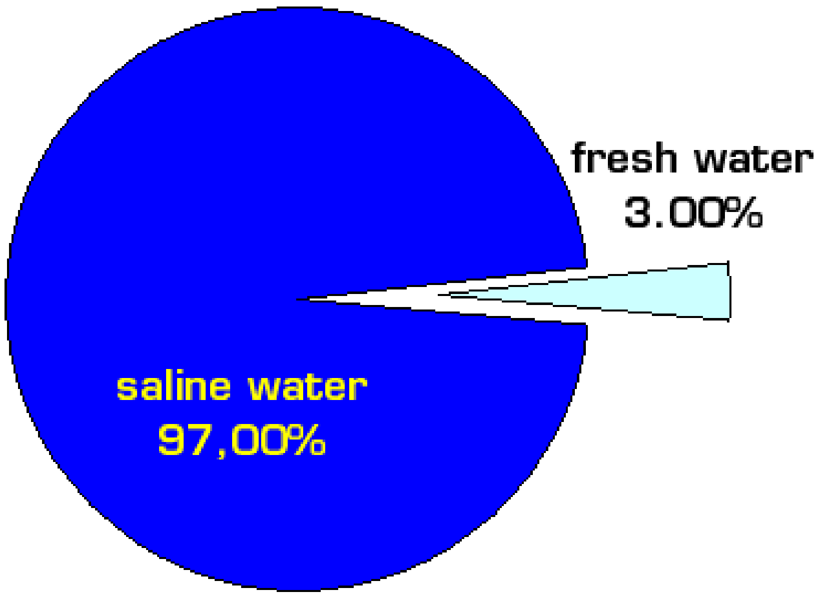
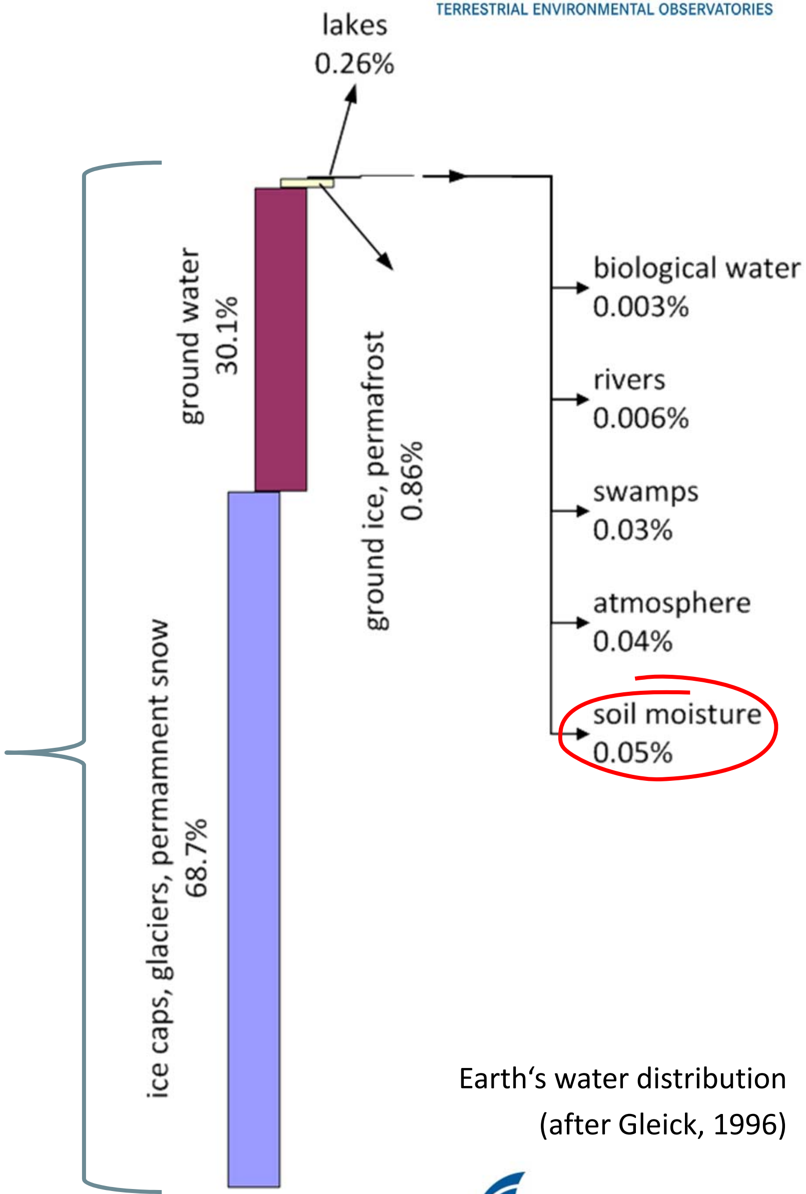
Water – Essential for Life on Earth

70.9% of earth surface is covered by water





Earth's water distribution
(after Gleick, 1996)

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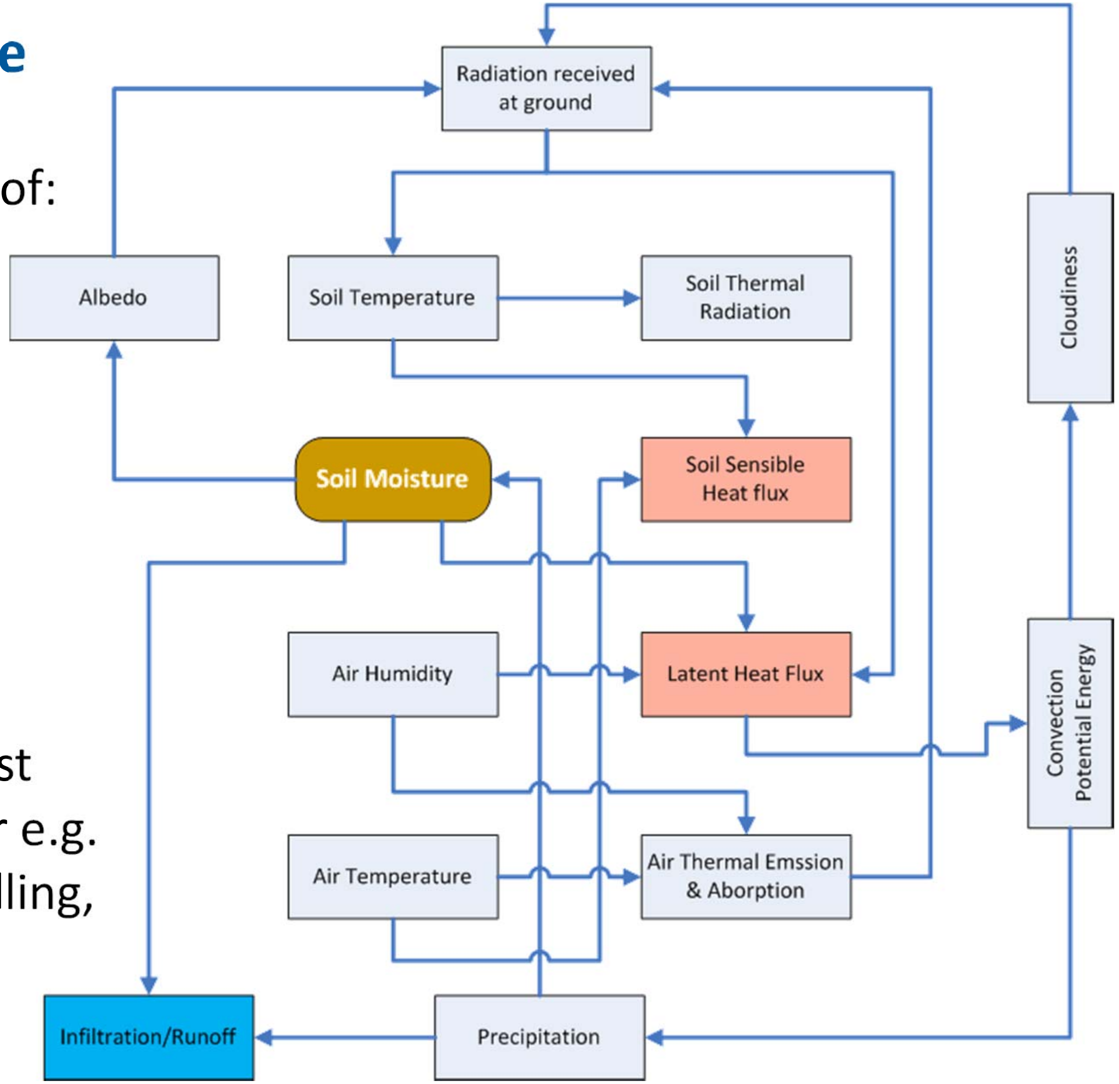
Importance of Soil Moisture

Soil Moisture controls distribution of:

- Infiltration and surface run-off
- Incident solar radiation in soil sensible and latent heat fluxes

Soil moisture is one of the most important geophysical parameter e.g. for climate or hydrological modelling, agriculture



Links between soil moisture and atmospheric (after Entekhabi et al. 1996)

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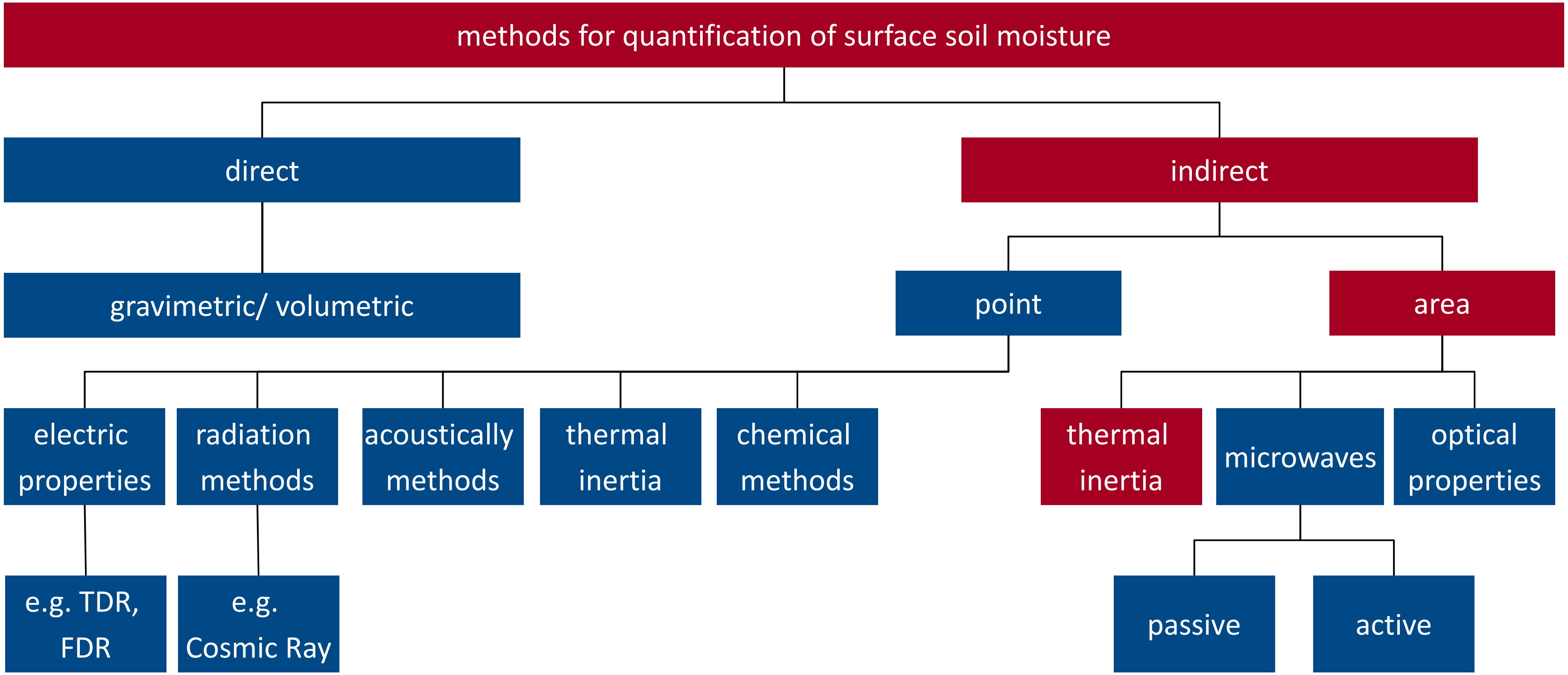
Quantification Methods of Soil Moisture



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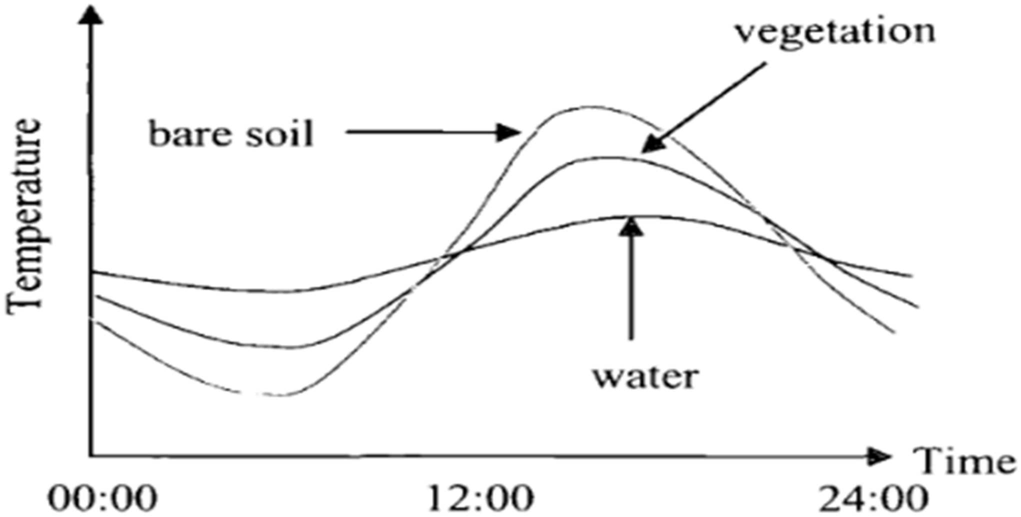
Thermal inertia [*P*]

- Response of a material to temperature changes



$$P = \sqrt{kpc}$$

k = thermal conductivity
p = density
c = specific heat capacity

- Thermal inertia of soil cannot be measured by remote sensing techniques directly → models needed

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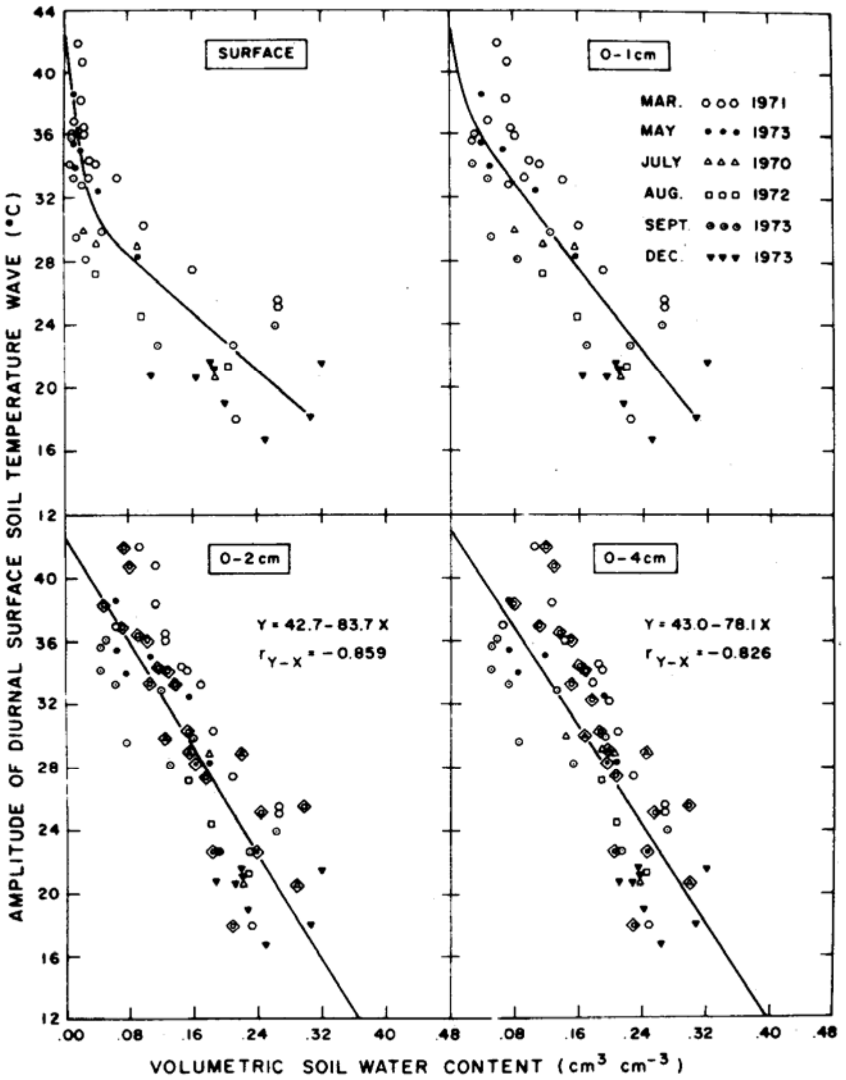
Diurnal Temperature Variation versus Soil Moisture



Summary of results for the diurnal temperature variation versus soil moisture [*Idso et al.*, 1975*a*].

Simple Approach of Apparent Thermal Inertia – ATI *(Price 1977)*

$$ATI = \frac{(1-A)}{(\Delta T)}$$

A = *Albedo*

ΔT = *Temperature change during the caption of two thermal data sets*

Limitation:

- No consideration of solar declination
- Overestimation of the influence of albedo
- Further effects not considered:
  eg. wind, roughness, evapotranspiration of vegetation etc.

ATI model does not meet the requirements of precise soil moisture retrieval

→ ***Real Thermal Inertia***

Outline

- Experimental Design
- Data Acquisition
- Real Thermal Inertia 2 Times Model
- Results
- Outlook

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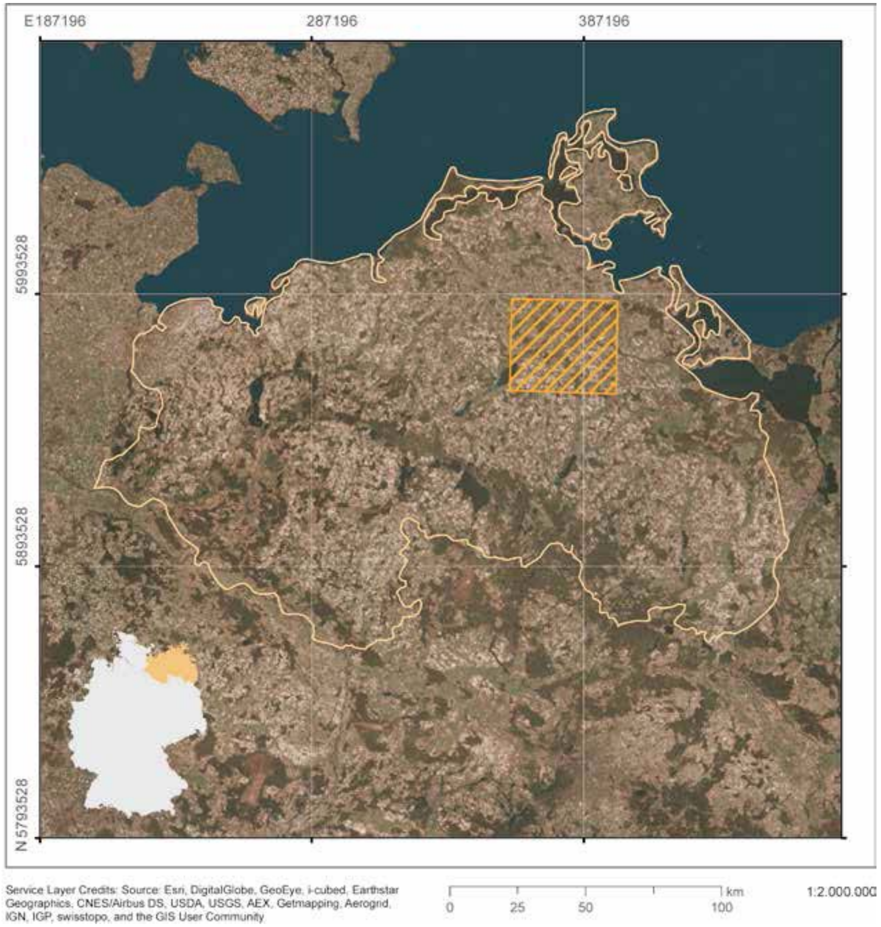
2013 Thermal Campaign

- TERENO-Northeastern German Lowland Observatory / DEMMIN® Testsite
  (Detailed Information – Poster Session on Tuesday)
- Installed by DLR Neustrelitz in 1999
- Since 2009 cooperation in TERENO-NE (coordinated by GFZ Potsdam)
  - Strong expansion of instruments
- 40 agro-meteorologic stations (20 DLR, 20 GFZ)
- 62 soil moisture stations

- Multitemporal Experiment
  08.07.2013 – 5 PM
  08.07.2013 – 8 PM
  09.07.2013 – 5 AM
  09.07.2013 – 9 AM
  09.07.2013 – 1 PM
- in situ measurements of surface temperature, soil temperature and soil moisture close to acquisition time
- 162 target points at different landuses






Data

Thermal (BGR Hannover)

- Infratec VarioCam hr head 600
- Spatial Resolution: *640 x 480 Pixel*
- Spectral coverage : *7 – 14 µm*

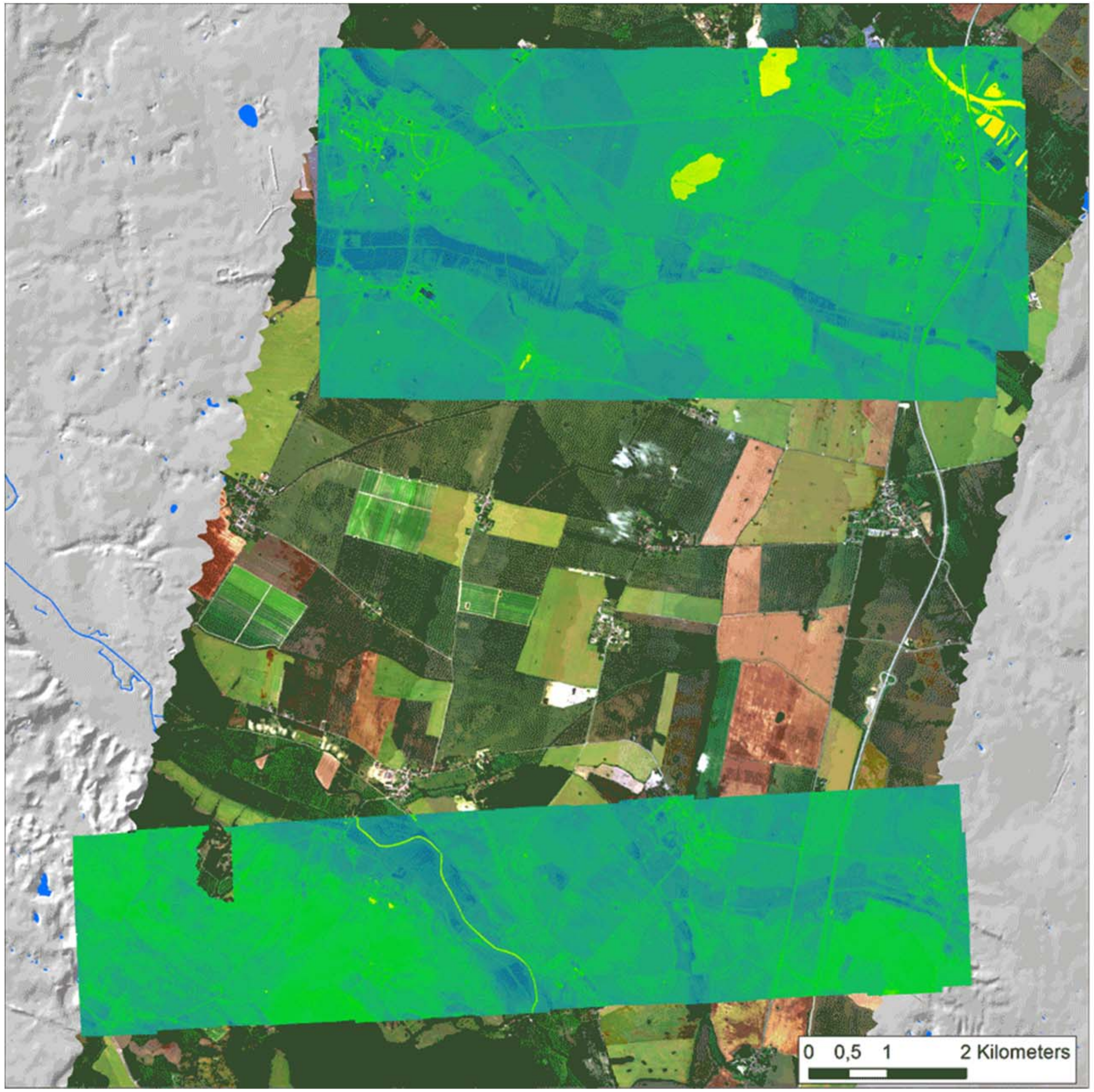
Hyperspectral (UFZ Leipzig)

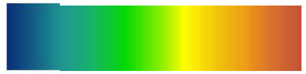
- AISA Dual
- Spatial Resolution: *300 Pixel across track*
- Spectral coverage : *0.4 – 2.5 µm*

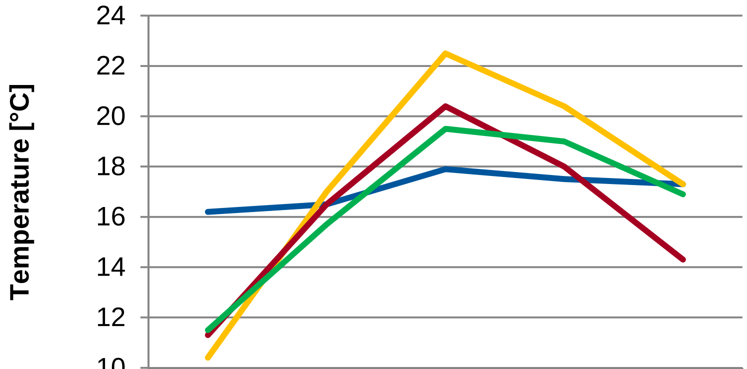
AISA Eagle (VNIR) | AISA Hawk (SWIR)

Marcin Wozny (BGR)

Diurnal variation of surface Temperature







	3 UTC	7 UTC	11 UTC	15 UTC	18 UTC
water	16,2	16,5	17,9	17,5	17,3
winter barley	10,4	17	22,5	20,4	17,3
sugar beet	11,3	16,5	20,4	18	14,3
forest	11,5	15,7	19,5	19	16,9

water — winter barley — sugar beet — forest

03:00 UTC

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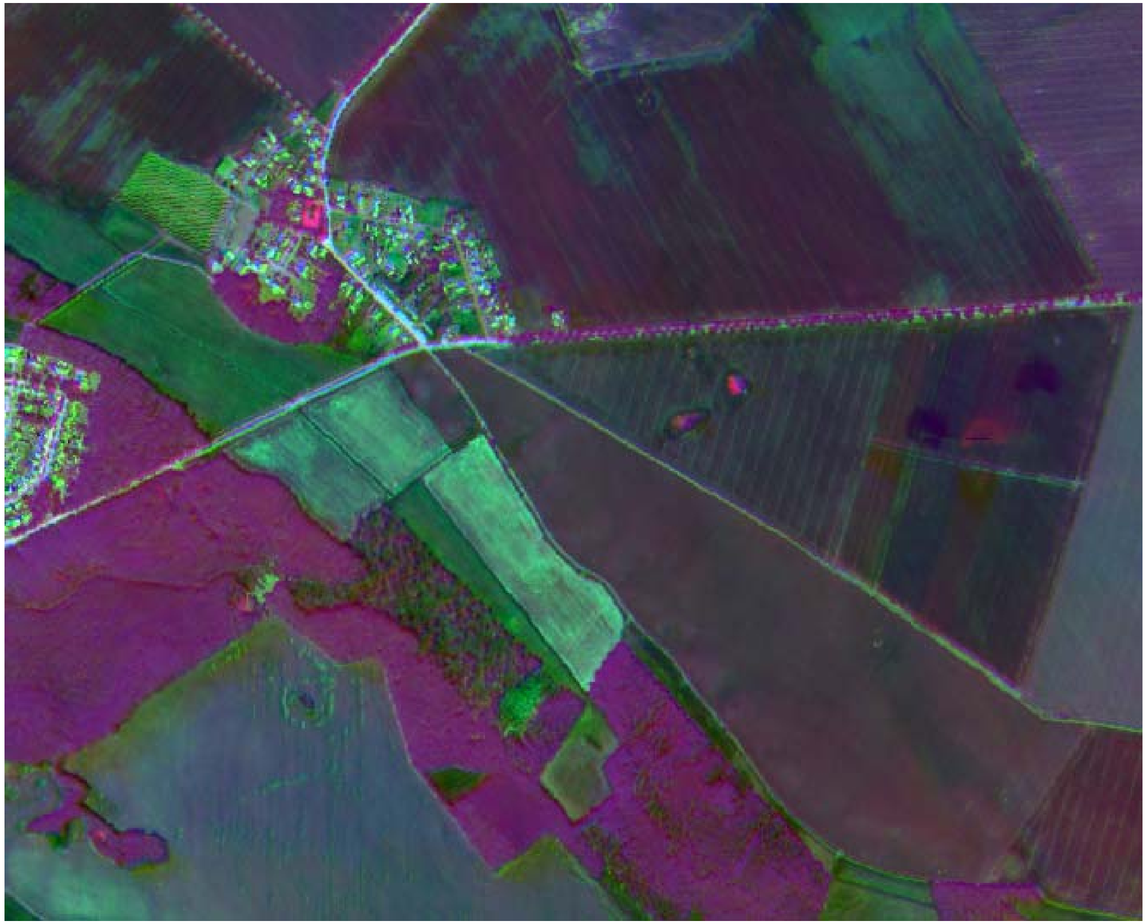
Diurnal variation of surface temperature

Multitemporal mosaic (3 UTC / 11 UTC / 18 UTC)



Differences of thermal inertia

- between crop types
- within fields

Potential reasons

Variations of internal factors

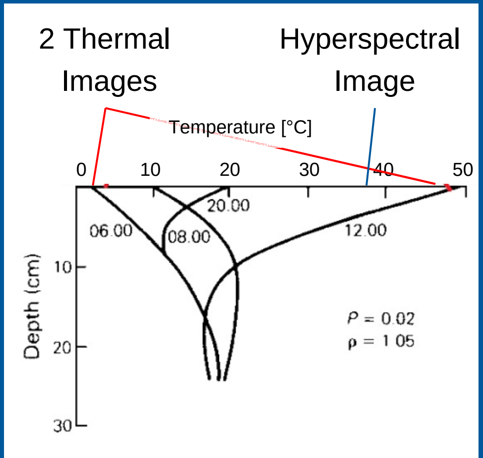
- plant density
- plant vitality
  (→ plant water content)
- soil type
- soil moisture

Real Thermal Inertia 2 Times Model

INPUT

Variable Input Parameter

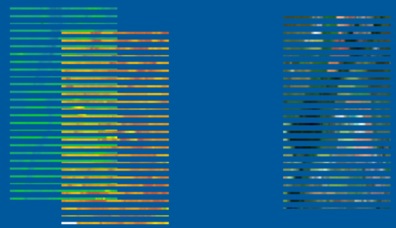
- Albedo → Hyperspectral Image Data



Constant Input Parameter

- solar Radiation
- solar declination
- latitude of observation
- longitude of observation

Calculation



$$P = \frac{2SoC_1A_1\frac{(1-A)}{(\delta T)}}{(\sqrt{\omega})\sqrt{(1+\left(\frac{1}{b}\right)+\frac{1}{(2b^2)})}}$$

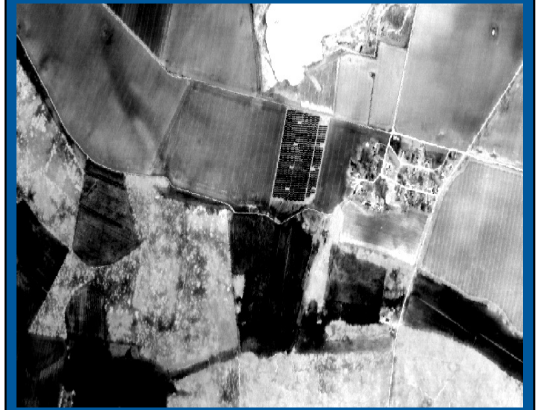
Diffusion Equation with linearized boundary conditions

solved with Fourier analysis assuming two coefficients of the series development are nearly equal

(after Carslaw and Jaeger, 1959)

Result

Real Thermal Inertia Image



low *high*

- compensation of albedo effects
- compensation of solar effects

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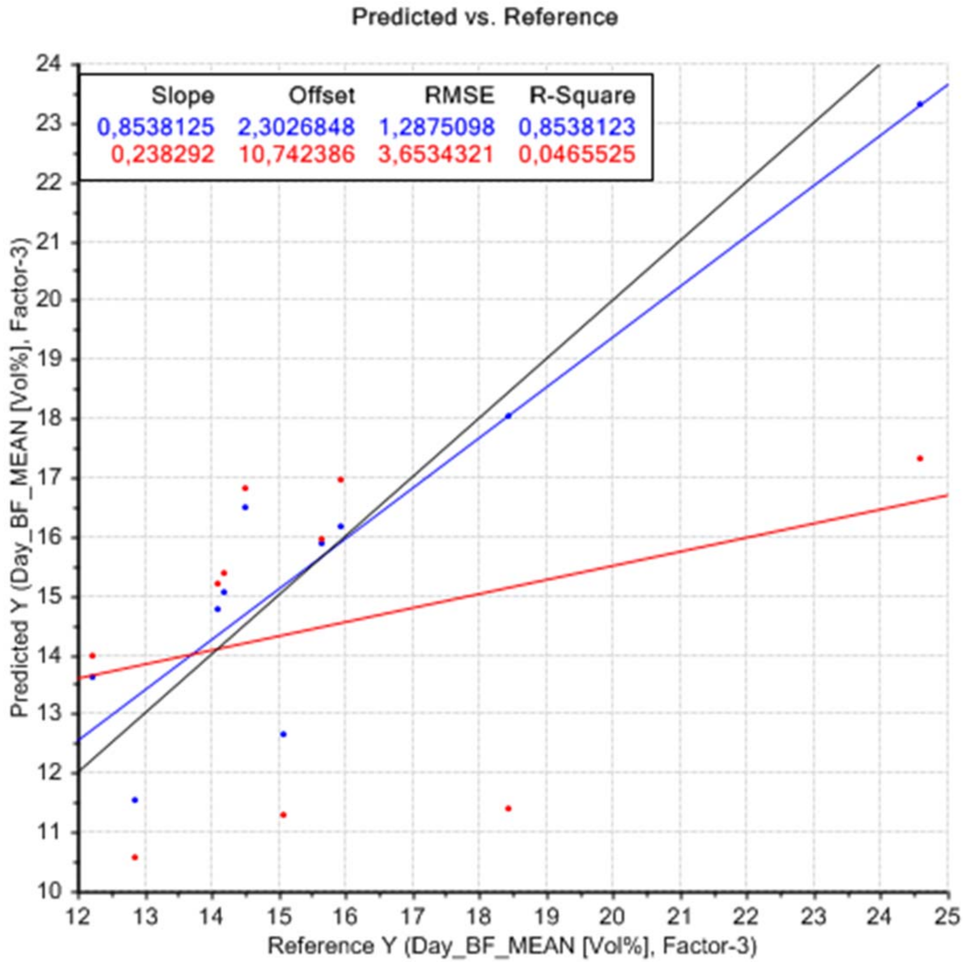
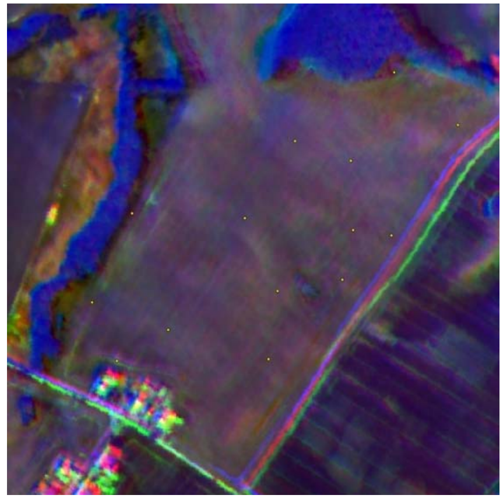
PLSR results for winter barley (08./09.07.2013)

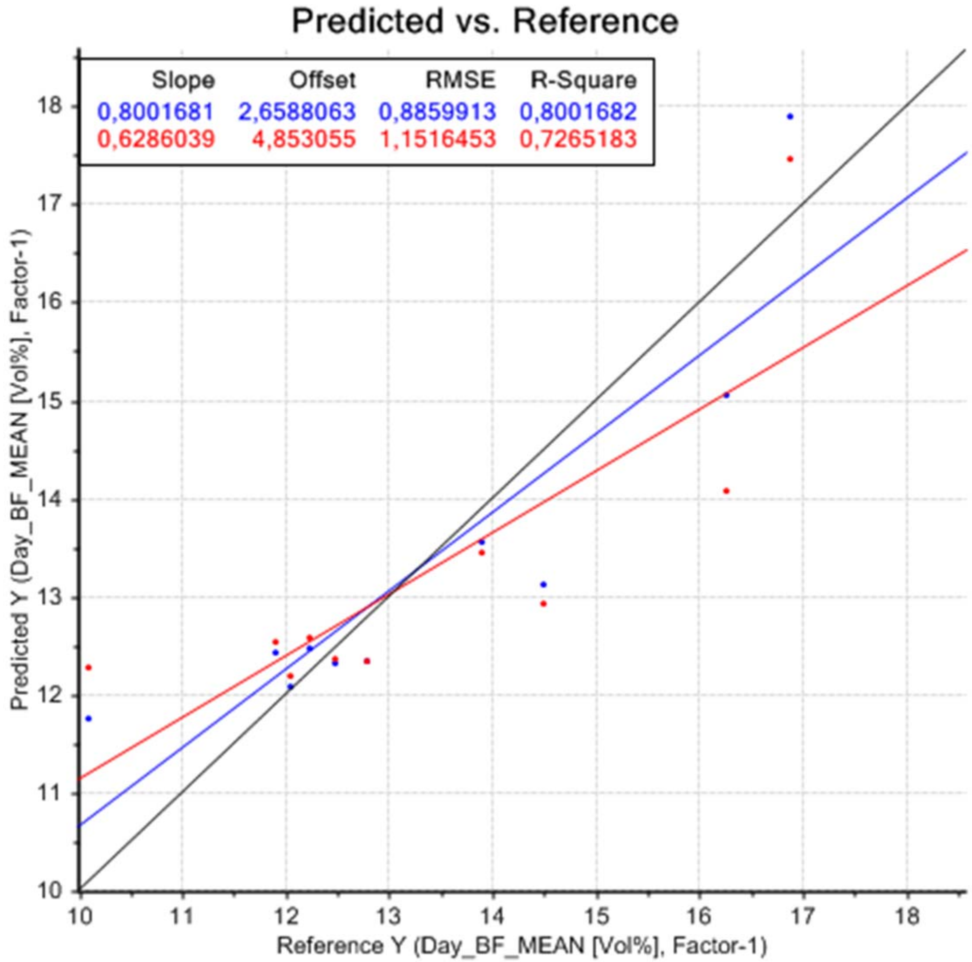
Winter barley

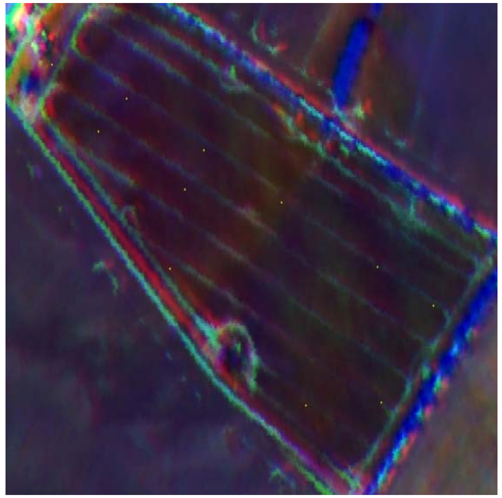




PLSR Results for sugar beet (08./09.07.2013)

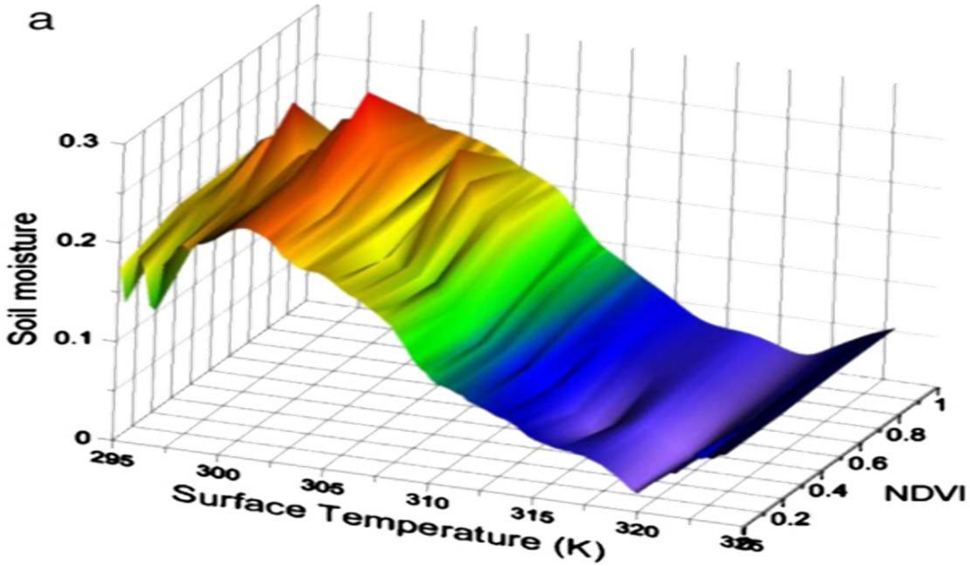
Sugar beet





Discussion and Outlook

- Good results for areas with low vegetation cover (< 50%)
- Actual no consideration of evapotranspiration



source:
Sobrino et al. / Remote Sensing of Environment 117 (2012) 415-428

Outlook

- Integration of evapotranspiration needed for vegetation covered areas
- Refine algorithm for combination with hyperspectral data
- Combination with data of TERENO DEMMIN agro-meteorological and soil moisture network

Thank you for your attention

Contact: *Dr. Daniel Spengler*
daniel.spengler@gfz-potsdam.de